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Research paper

Spectral Amplitude Coding Optical CDMA: Performance Analysis on Free Space Optical Channel

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Abstract

In this paper, we investigate the performance of Spectral Amplitude Coding Optical Code Division Multiple Access technique based on Free Space Optical channel. SAC OCDMA is one of the most popular multiplexing techniques since many years and FSO is gaining popularity and is very useful especially in point to point communication. The system presented in this paper utilizes Walsh Hadamard code as signature code. The coder and decoder structures are based on optical filters of fiber Bragg gratings (FBGs). This system focuses on the performance analysis of FSO based systems for subtropical regions. This paper demonstrates the error rate performance in the form of eye diagrams/BER under varying channel gain and link distances. Five cases have been taken which shows that SAC OCDMA FSO system is reliable even for distances sufficient to overcome the last mile problem.

Key words: *Spectral Amplitude Coding, Optical CDMA, Free Space Optics, last-mile solution, channel attenuation.*

1. Introduction

Free Space Optics (FSO) can deliver an effective line-of-sight, wireless, and high bandwidth communication between two places [1]. It can be considered as an alternative to the Optical Fiber cable or RF/Microwave systems especially when the physical connections are impractical due to several considerations. Next Generation Network (NGN) is independent of protocols and interfaces provide the provision of different high-speed services compatible to all previous & new technology for its realization. FSO has proved to be the ideal choice for the access technology of NGN. Recently many researchers have started working on FSO[6– 15].In this research we have practically analysed the integration of FSO in NGN in diverse atmospheric conditions using Spectral Amplitude Coding Optical CDMA [2].The analysis of Walsh Hadamard codes based SAC OCDMA system for FSO environment in subtropical regions such as Pakistan. Spectral Amplitude Coding OCDMA is a multiplexing technique with asynchronous operation, high level security and increased network capacity. SAC OCDMA has been in focus of many researchers for many years [3-5]. Due to its features and usefulness it is being used in many ways especially in access and core networks. It is now widely accepted that optical wireless technology can prove to be viable alternative to the radio and microwave [15-20]**.** Many encoding schemes are used in OCDMA (Optical Code Division Multiple Access Network) but SAC (Spectral Amplitude Codes) is widely used as it is considered an effective arrangement to eliminate dominant noise called MAI (Multi Access Interference [21]. SAC is a technique of OCDMA to encode and decode data bits by utilizing spectral components of the broadband source [22]. This section is followed by section II which describes the system model. Section III gives the performance analysis in the form of eye diagrams using BER monitor for various ranges and channel attenuation factors. Section IV discusses the results and section V concludes the paper. This is followed by section VI and VII for acknowledgment and references.

2. System Model

Figure1 shows the block diagram model of this system. In this model 3 users are taken where user 3 is turned OFF. Between the transmitter and receiver, the channel taken here is FSO. As the length of FSO channel is usually smaller, in this model different lengths of FSO channel are taken one by one and the performance has been observed on the receiver side via BER analyzers.

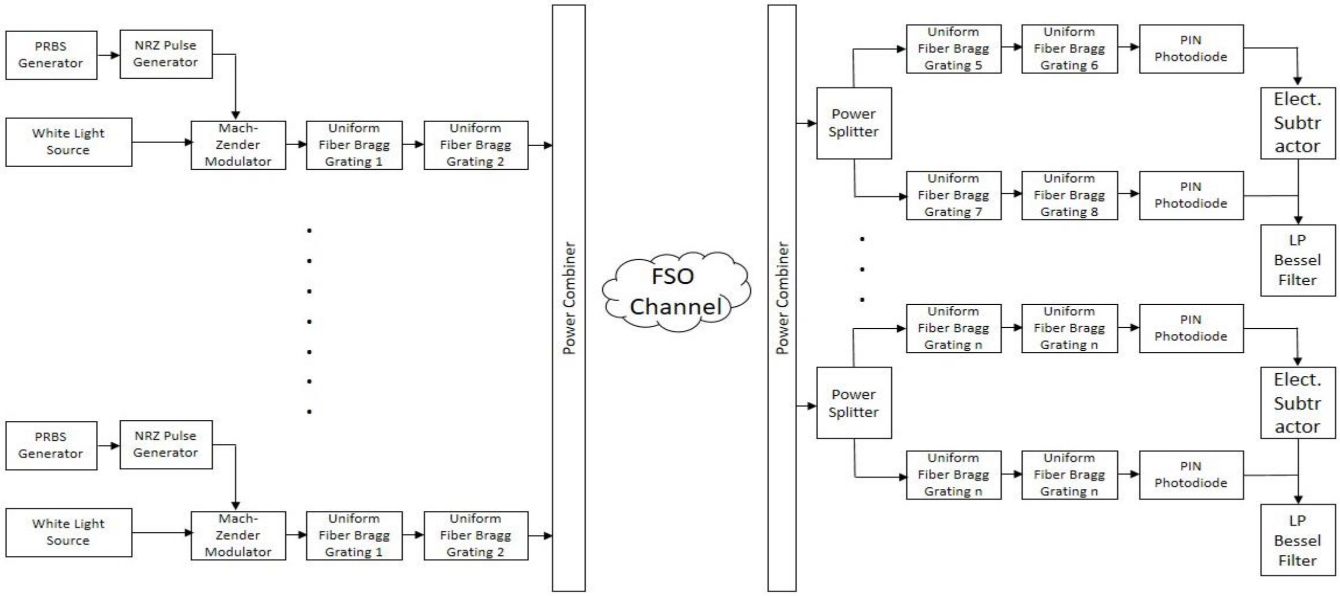


Fig. 1: SAC OCDMA FSO channel system model

Table 1: SAC OCDMA system parameters

	Parameter	Value
1.	Power	16dBm
2.	Extinction Ratio	30dB
3.	Responsivity	1A/W
4.	Receiver aperture diameter	7.5cm
5.	Beam divergence	0.25m/rad
6.	Transmitter loss	1dB
7.	Additional loss	1dB

Table 1 shows the system parameters and figure 2 shows the architecture of the system made in Opti-system software version 7. In this system we have taken three users each assigned with a unique sequence code that serves as its signature sequence. User 1 and 2 are ON and user 3 is OFF. Every user transmitter is made of PRBS (Pseudo Random Bit Sequence generator), NRZ (Non-return to zero) Pulse Generator, white light source, and Mach-zander (MZ) modulator. The MZ modulator is then connected with 2 UFBGs (uniform fiber brag grating system). UFBG1 has wavelength 1550.1nm while UFBG2 has wavelength 1552.5nm. Similarly, other wavelengths are 1550.9nm, 1552.5nm, 1550.1nm, 1550.9nm.

User # 1uses λ_1 = 1550.1 nm and λ_2 = 1552.5 nm
User #2 uses λ1 = 1550.9 nm and λ_2 = 1552.5 nm
User #3 uses λ1 = 1550.1 nm and λ_2 = 1550.9 nm

These UFBG systems are connected to the Power combiner, which is then connected with FSO channel. This channel is tested on numerous cases where range and attenuation factor have been varied to analyze the performance of this system.The FSO link attenuation can reach 120 dB/km to 480 dB/km under severe conditions during the winter season [23-25]. Therefore we have taken 100dB to 300dB attenuation factor for experimenting the performance of this system. At the receiver side, this FSO channel is connected to the Power splitter. Power splitter has three outputs for three users. For every user there are four UFBG systems, which are then connected with PIN photo-detectors whose outputs are electrically subtracted and applied to a Low Pass Bessel filter. The filtered output is then analyzed in BER analyzer with respect to its input side taken from NRZ pulse generator and PRBS generator. Each user has its own set of wavelengths. For user1 the wavelengths are 1550.1nm, 1552.5nm, 1548.5nm, 1550.9nm. Similarly, for user 2 the wavelengths are 1550.9 nm, 1552.9 nm, 1548.5 nm, 1550.1 nm and for user 3 the wavelengths are 1550.1 nm, 1550.9 nm, 1548.5 nm, 1552.5 nm.

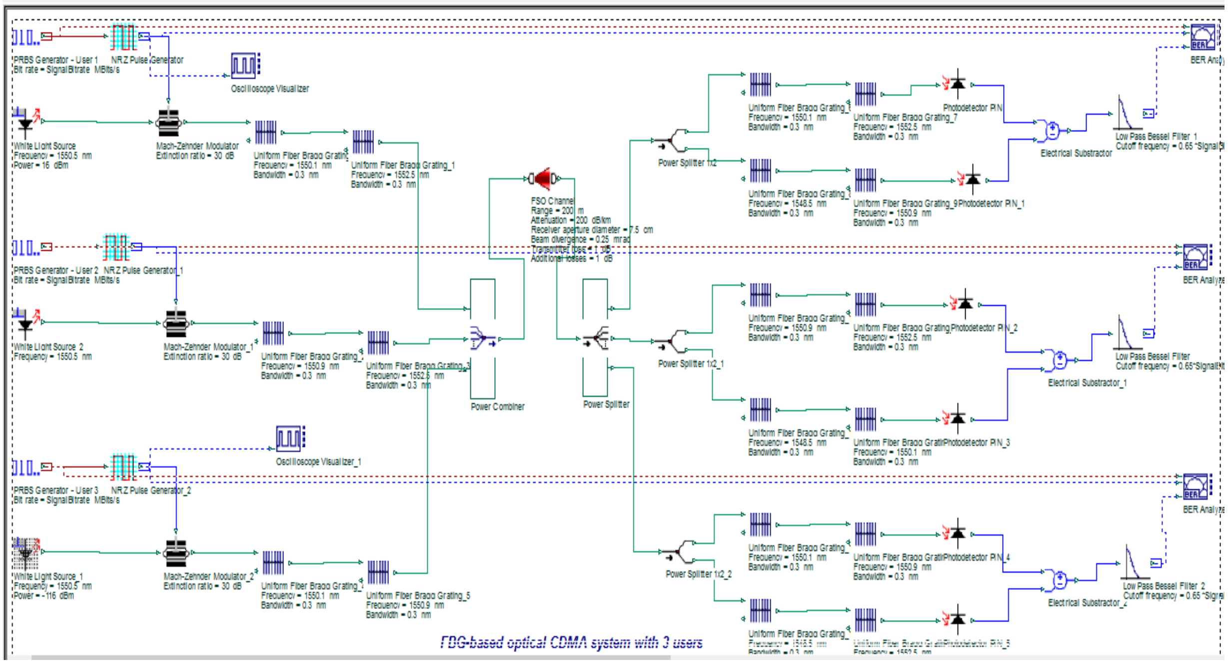


Fig. 2: Architecture of FSO based SAC OCDMA system

3. Performance Analysis

In this paper we have taken five cases. In every case, range and attenuation factor have been changed to analyze the performance of FSO SAC OCDMA system. Figure 3 is given where every user's eye diagram is shown for each case. The different ranges taken are from 200m to 5km whereas attenuation factor is from 100dB/km to 300dB/km. It must be noted that up to certain distance the BER performance of SAC-OCDMA network is satisfactory however it experiences a sudden drop in the performance once the distance is increased beyond that point. It is shown that by increasing the range of FSO channel the system gets all noisy and so we need to vary the attenuation factor and find the values where again system is providing acceptable output.

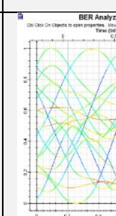
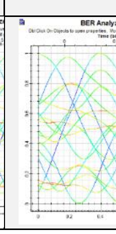
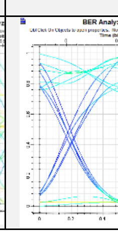
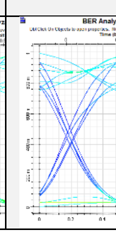
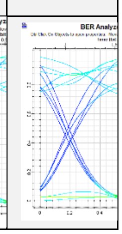
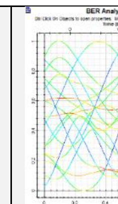
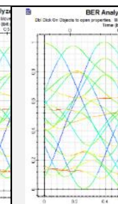
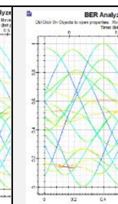
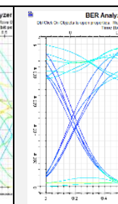
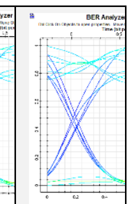
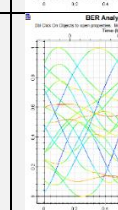
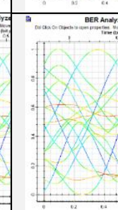
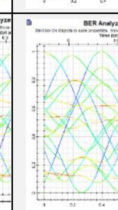
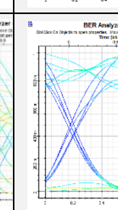
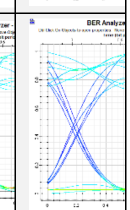
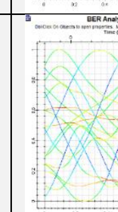
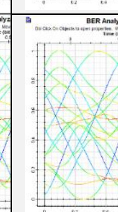
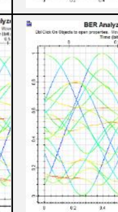
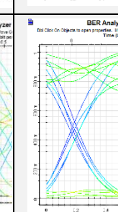
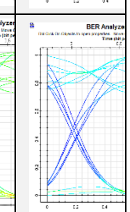
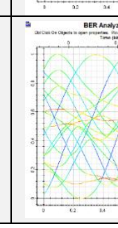
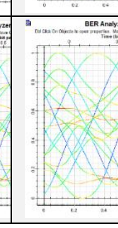
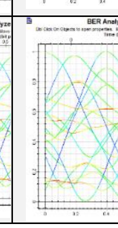
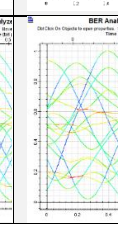
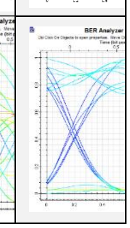
RANGE / ATTENUATION	R1 = 5Km	R1 = 2Km	R1 = 1Km	R2 = 500m	R3 = 200m
A1 = 100 dB/km					
A2 = 150 dB/km					
A3 = 200 dB/km					
A4 = 250 dB/km					
A5 = 300 dB/km					

Fig.3: Eye Diagrams for 5 cases of FSO SAC OCDMA

4. Results

The eye diagrams of the proposed system are presented in figure 3. The minimum range/distance taken is 200m to the maximum of 5km, while the attenuation is taken from 100dB/km to 300dB/km.

As Pakistan is a subtropical region the attenuation at maximum taken is 300dB/km. For coastal areas where foggy weather is common the maximum attenuation seen is 480dB/km [23-25]. This system can withstand attenuation of 100dB till 1Km as shown in the figure 3. As attenuation is increased to 150dB/km the signal starts to degrade from 1Km to 5Km and successful transmission of data is possible till 500m range. Further, when we increase the attenuation to 200dB/km to 250dB/km, the system shows same response as shown in the previous case, i-e successful reception of data till 500m range. Once the attenuation is made 300dB/km the signal drops and possible signal transmission is only till 200m range, which shows the worst possible case in a subtropical region. The BER value under all successful transmission is around 10^{-21}. However a sharp degradation in BER value is noticed once the attenuation value and distance is increased.

5. Conclusion

This paper shows that SAC-OCDMA is a suitable option for the FSO channel operating within few kilometres. The performance of FSO channel heavily depends on the attenuation and experiences sudden drop once the link distance is increased. Therefore, it is imperative to determine the optimal values of link distances given certain channel conditions.

6. Acknowledgment

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